Office of Science

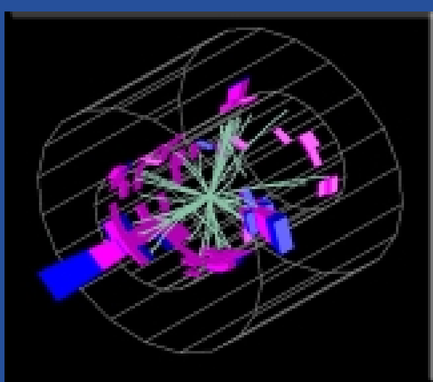
U.S. Department of Energy

High Energy Physics

The Office of Science's High Energy Physics (HEP) program provides the great majority of Federal support for research in high energy physics, which is aimed at understanding the fundamental nature of matter, energy, space, and time. The HEP program funds research at more than 100 universities in 36 states and 10 national laboratories in 6 states. HEP also operates world-class research facilities at three laboratories, serving 3,500 researchers from universities and laboratories each year.

The Opportunity

Since the dawn of civilization, man has sought to discover nature's ultimate building blocks and forces. From the "Earth, air, fire, and water" of the ancients to the present standard model of quarks, gluons, and leptons, each new level of structure unveiled has opened up new worlds, new insights, and the creation of revolutionary new tools for mankind's use.



Simulation of a Higgs boson event as it might appear in a detector at Fermilab

As we reach the centennial of Einstein's theory of relativity, we may find ourselves at the threshold of discoveries equally profound. What gives matter its mass? Have we at last identified nature's ultimate constituents, or will we find a mirror set of "supersymmetric" particles? What is the dimensionality of space—are there extra dimensions hidden from us, and why? What is the role of the neutrino in the universe? What are the mysterious "dark energy" and "dark matter" that seem to make up 95% of the universe? Why is the remaining 5% of the universe made only of matter, with hardly any antimatter? At the end of this decade, our views of matter and the universe may be changed forever.

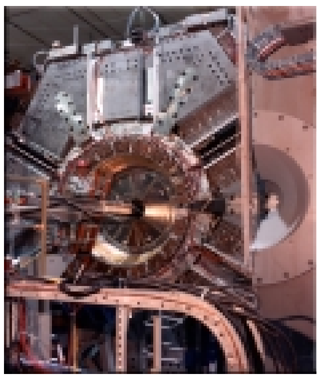
The Challenge

The major tools at hand to explore these fundamental questions are the high energy accelerator facilities built and operated by the Office of Science, and used by the talented and imaginative scientists that it supports at its laboratories and universities. With these tools, the HEP program will pursue the following challenges:

Higgs and the Origin of Mass. The Large Electron-Positron Collider at CERN was shut down in 2000, leaving behind a tantalizing hint of the long theorized, but as yet unseen Higgs boson. The Higgs is believed to be the source of mass for all elementary particles, and its discovery would mark a profound advance in science. The Large Hadron Collider (LHC) now being constructed at CERN, will be a strong contender to find the Higgs, and American physicists will participate in that research. However, the LHC cannot begin an intense physics program before the spring of 2007, leaving the Tevatron collider at the Office of Science's Fermi National Laboratory with a window of opportunity to make this important discovery. This collider and its two detectors completed major upgrades and began operating in March 2001. With protons and antiprotons colliding at energies of one trillion electron volts (1 TeV), the Tevatron will be the world's highest energy physics research facility until the LHC is operational.

Beyond the Standard Model. Theoretical explorations beyond the Standard Model suggest that a new class of "supersymmetric" particles may be discovered, or that extra dimensions may exist beyond the familiar four dimensions of space/time. The upgraded Tevatron may be able to test these theories. Confirming either theory would represent a major advance in human knowledge.

Matter and the Universe. Scientists using the B-Factory and its BaBar detector at the Stanford Linear Accelerator Center (SLAC) have an opportunity to explain the vast preponderance of matter over antimatter in the universe. Electrons and positrons colliding at energies of several billion electron volts allow the study of a small asymmetry in the way B mesons decay into other particles. The asymmetry is known as Charge-Parity (CP) violation and was first discovered in 1964. CP violation is believed to be at least partly responsible for the survival of more matter than antimatter after the Big Bang origin of the universe.



The BaBar detector at the B-Factory

The Role of Neutrinos. The neutrino is a particle that plays a key role in the interactions of elementary particles and in astrophysical processes. Neutrinos are created and detected in one of three "flavors": electron, muon, or tau. The current theory of elementary particles, called the Standard Model, requires that neutrinos be massless, but experimental results now provide compelling evidence that they do have mass. If they have mass, a neutrino created in one flavor would "oscillate" among different flavors as it travels. A new Fermilab experiment called MiniBooNE will begin taking data in 2002 to test whether muon neutrinos oscillate to electron neutrinos, as indicated by an earlier experiment. Another new detector called MINOS is being assembled in a Minnesota mine and a beam of neutrinos for it is being built at Fermilab. With this long baseline experiment (450 miles), physicists will make precise measurements of neutrino mass. Results from MiniBooNE and MINOS will help scientists understand the role of this unique particle in particle interactions and in the evolution of the universe.

Tevatron acclerator at Fermi National Laboratory

Dark Energy and Matter. At the Office of Science's Lawrence Berkeley National Laboratory, studies of supernovae have indicated that the universe is expanding at an accelerating rate, due to "dark energy," estimated to comprise 70% of the critical density of the universe. "Dark matter," which emits no radiation, makes up another 25% of the critical density, with normal matter contributing only 5%. Explaining these mysterious forms of matter and energy is another high priority of the HEP program.

Investment Plan

HEP will assign priority to exploiting investments in new and upgraded research facilities to search for the Higgs boson and new physics beyond the Standard Model, to study CP violation in B-meson decays, and to understand the key role of the neutrino. HEP will also continue its R&D investments in a possible future linear collider.

The Benefits

The Office of Science's program in high energy physics substantially increases our fundamental understanding of matter and energy. In addition, unique HEP research facilities and a strong research program in high energy physics help the United States maintain a leading role in the field, educate young people in science, and transfer to industry the technologies developed for research.

Contact

Dr. S. Peter Rosen, Associate Director
High Energy & Nuclear Physics
Office of Science
U.S. Department of Energy, Headquarters
19901 Germantown Road
Germantown, MD 20874-1290
Phone: 301-903-3713 Fax: 301-903-3833
E-mail: Peter.Rosen@science.doe.gov
http://doe-hep.hep.net/home.html